RISK-BASED DECISION-MAKING GUIDELINES

Volume 3
Procedures for Assessing Risks

Applying Risk Assessment Tools

Chapter 8 — What-if Analysis

Chapter Contents

This chapter provides a basic overview of the what-if analysis technique and includes fundamental step-by-step instructions for using this methodology to postulate potential upsets that may result in accidents. Following are the major topics in this chapter:

See examples of what-if analyses in Volume 4 in the What-if Analysis directory under Tool-specific Resources.

Summary of What-if Analysis

Questions	Responses
▪ "What if {a specific accident} occurs?" ▪ "What if {a specific system} fails?" ▪ "What if {a specific human error} occurs?" ▪ "What if {a specific external event} occurs?"	"{Immediate system vessel condition} "potentially leading to {accident of interest} "if {applicable safeguards} fail"

Summary of What-if Analysis

What-if analysis is a brainstorming approach that uses broad, loosely structured questioning to (1) postulate potential upsets that may result in accidents or system performance problems and (2) ensure that appropriate safeguards against those problems are in place.

Brief summary of characteristics

- A systematic, but loosely structured, assessment relying on a team of experts brainstorming to generate a comprehensive review and to ensure that appropriate safeguards are in place
- Typically performed by one or more teams with diverse backgrounds and experience that participate in group review meetings of documentation and field inspections
- Applicable to any activity or system
- Used as a high-level or detailed risk assessment technique
- Generates qualitative descriptions of potential problems, in the form of questions and responses, as well as lists of recommendations for preventing problems
- The quality of the evaluation depends on the quality of the documentation, the training of the review team leader, and the experience of the review teams

Most common uses

- Generally applicable for almost every type of risk assessment application, especially those dominated by relatively simple failure scenarios
- Occasionally used alone, but most often used to supplement other, more structured techniques (especially checklist analysis)

Example

Summary of the What-if Review of a Vessel's Compressed Air System

What if … ?	Immediate System Condition	Ultimate Consequences	Safeguards	Recommendations
1. The intake air filter begins to plug	Reduced air flow through the compressor, affecting its performance	Inefficient compressor operation, leading to excessive energy use and possible compressor damage Low or no air flow to equipment, leading to functional inefficiencies and possibly outages	Pressure/vacuum gauge between the compressor and the intake filter Annual replacement of the filter Rain cap and screen at the air intake	Make checking the pressure gauge reading part of someone's weekly round **OR** Replace the local gauge with a low pressure switch that alarms in a manned area
2. Someone leaves a drain valve open	High air flow rate through the open valve to the atmosphere	Low or no air flow to equipment, leading to functional inefficiencies and possibly outages Potential for personnel injury from escaping air or blown debris	Small drain line would divert only a portion of the air flow, but maintaining pressure would be difficult	—
• • •	• • •	• • •	• • •	• • •

Limitations of What-if Analysis

- **Likely to miss some potential problems**
- **Difficult to audit for thoroughness**
- **Traditionally provides only qualitative information**

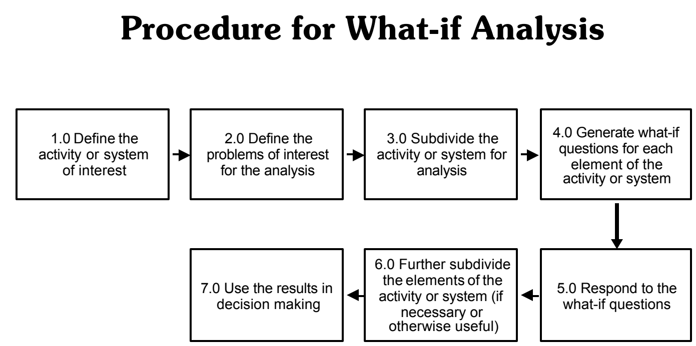
Limitations of What-if Analysis

Although what-if analysis is highly effective in identifying various system hazards, this technique has three limitations:

Likely to miss some potential problems. The loose structure of what-if analysis relies exclusively on the knowledge of the participants to identify potential problems. If the team fails to ask important questions, the analysis is likely to overlook potentially important weaknesses.

Difficult to audit for thoroughness. Reviewing a what-if analysis to detect oversights is difficult because there is no formal structure against which to audit. Reviews tend to become "*mini-what-ifs,*" trying to stumble upon oversights by the original team.

Traditionally provides only qualitative information. Most what-if reviews produce only qualitative results; they give no quantitative estimates of risk-related characteristics. This simplistic approach offers great value for minimal investment, but it can answer more complicated risk-related questions only if some degree of quantification is added.



Procedure for What-if Analysis

The procedure for performing a what-if analysis consists of the following seven steps:

1.0 Define the activity or system of interest. Specify and clearly define the boundaries for which risk-related information is needed.

2.0 Define the problems of interest for the analysis. Specify the problems of interest that the analysis will address (safety problems, environmental issues, economic impacts, etc.).

3.0 Subdivide the activity or system for analysis. Section the subject into its major elements (e.g., locations on the waterway, tasks, or subsystems). The analysis will begin at this level.

4.0 Generate what-if questions for each element of the activity or system. Use a team to postulate hypothetical situations (generally beginning with the phrase "what if …") that team members believe could result in a problem of interest.

5.0 Respond to the what-if questions. Use a team of subject matter experts to respond to each of the what-if questions. Develop recommendations for improvements wherever the risk of potential problems seems uncomfortable or unnecessary.

6.0 Further subdivide the elements of the activity or system (if necessary or otherwise useful). Further subdivision of selected elements of the activity or system may be necessary if more detailed analysis is desired. Section those elements into successively finer levels of resolution until further subdivision will (1) provide no more valuable information or (2) exceed the organization's control or influence to make improvements. Generally, the goal is to minimize the level of resolution necessary for a risk assessment.

7.0 Use the results in decision making. Evaluate recommendations from the analysis and implement those that will bring more benefits than they will cost in the life cycle of the activity or system.

1.0 Define the activity or system of interest

- **Intended functions**
- **Boundaries**

1.0 Define the activity or system of interest

Intended functions. Because all risk assessments are concerned with ways in which intended functions can fail, a clear definition of the intended functions is an important first step in any assessment. This step does not have to be formally documented for most what-if analyses.

Boundaries. Few activities or systems operate in isolation. Most interact with others. The analyst should clearly define the boundaries of the study, especially areas where a vessel will transit, or boundaries with support systems such as electric power and compressed air. In this way, the analyst can avoid the following:

- Overlooking key elements of an activity or system at interfaces
- Penalizing an activity or system by associating other equipment with the subject of the study

Examples

Definition for a vessel operational study

Deep Draft Oil Tankers		
Intended Functions	Boundaries of Analysis	
	Within Scope	Outside of Scope
• Harbor transit • Docking • Unloading • Loading	• Operations within the controlled harbor's waterways • Onboard loading and unloading systems	• Operations outside of the harbor • Shoreside loading, unloading, and storage systems • Cargo other than liquids

Definition for an onboard compressed air system study

Compressed Air System		
	Boundaries of Analysis	
Intended Functions	Within Scope	Outside of Scope
• Provide compressed air at 100 psig • Remove moisture and contaminants from the air • Contain the compressed air	• Breaker supplying power to the compressor • Air hoses and piping at pneumatic equipment	• Power supply bus for the compressor • Air hose connections on pneumatic equipment

2.0 Define the problems of interest for the analysis

- Safety problems
- Environmental issues
- Economic impacts

2.0 Define the problems of interest for the analysis

Safety problems. The analysis team may be asked to look for ways in which improper performance of a marine activity or failures in a hardware system can result in personnel injury. These injuries may be caused by many mechanisms, including the following:

- Vessel collisions or groundings
- Person overboard
- Exposure to high temperatures (e.g., through steam leaks)
- Fires or explosions

Environmental issues. The analysis team may be asked to look for ways in which the conduct of a particular activity or the failure of a system can adversely affect the environment. These environmental issues may be caused by many mechanisms, including the following:

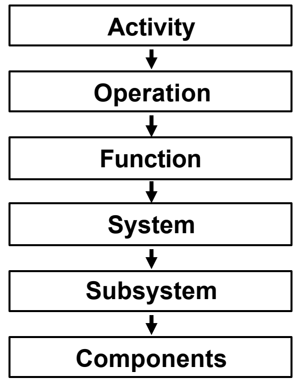
- Discharge of material into the water, either intentional or unintentional
- Equipment failures, such as seal failures, that result in a material spill
- Overutilization of a marine area, resulting in a disruption of the ecosystem

Economic impacts. The analysis team may be asked to look for ways in which the improper conduct of a particular activity or the failure of a system can have undesirable economic impacts. These economic risks may be categorized in many ways, including the following:

- Business risks, such as vessels detained at port, contractual penalties, lost revenue, etc.
- Environmental restoration costs
- Replacement costs, such as the cost of replacing damaged equipment

A particular analysis may focus only on events above a certain threshold of concern in one or more of these categories.

3.0 Subdivide the activity or system for analysis



3.0 Subdivide the activity or system for analysis

An activity or system may be divided at many different levels of resolution. Generally speaking, analysts should try to describe risk-related characteristics for an activity or system at the broadest level possible, based on availability of applicable data. The procedure for subdividing an activity or system is typically repetitive, beginning with a broad subdivision into major sections or tasks.

This strategy of beginning at the highest level helps promote effective and efficient risk assessments by (1) ensuring that all key attributes are considered, (2) encouraging analysts to avoid unnecessary detail, and (3) using a structure that helps to avoid overlooking individual components or steps if further subdivision is necessary.

Example

Systems associated with the vessel's compressed air system

- Compressor system
- Dryer system
- Distribution system

4.0 Generate what-if questions for each element of the activity or system

- "What if {a specific accident} occurs?"
- "What if {a specific system} fails?"
- "What if {a specific human error} occurs?"
- "What if {a specific external event} occurs?"

4.0 Generate what-if questions for each element of the activity or system

The brainstorming process is used by an analysis team to generate what-if questions. Two different types of teams may be assembled to generate the what-if questions:

- **Team Type 1: Subject matter experts.** These people are very knowledgeable about details of how the activity is conducted, or how the system is designed, maintained, and operated. While they can perform an analysis very efficiently, their closeness to the activity or system may keep them from seeing some issues.
- **Team Type 2: Objective technical personnel.** These people know little about the specific activity or system being analyzed, but they are technically knowledgeable and have experience with similar applications. They often do a very thorough job identifying different types of possible issues, but they sometimes overlook subtle issues unique to the specific application or spend too much time dwelling on unimportant issues.

Regardless of the type of team selected for brainstorming, the leader should observe the steps on the following page while conducting the analysis.

Procedure for generating what-if questions

Step 1. Remind the team of the analysis scope and objectives

Step 2. Allow a few minutes for participants to collect their thoughts

Step 3. Explain how questions will be collected

- First or loudest voice (brainstorming)
- Round robin (nominal group technique)
- Circulating lists (*brainwriting*)

Step 4. Explain the rules for questions

- OK to ask any question whatever
- OK to rephrase, combine, or broaden others' questions
- OK to speak *out of turn*
- OK to answer questions about design intent or capability, but not *what-if* questions
- OK to use a prepared list of questions
  - open brainstorming to collect *top-of-the-head* questions
  - focus brainstorming on specific process sections or subsystems
  - seed the group with your own questions
  - refocus the group only when several consecutive questions digress; expect and accept isolated irrelevant questions
  - use relevant checklist items to provoke additional questions

Step 5. Record the ideas as they are suggested, generally on a flipchart, overhead transparency, or by computer projection

Step 6. End the questioning after a reasonable time

Step 7. Organize the questions into logical groups for resolution; combine closely related items as appropriate and eliminate overlapping questions

If a different group will respond to the questions, the questions must be clearly worded, with enough detail for others to understand.

Example

What-if Questions for the Vessel's Compressed Air System	
Compressor system	• What if the intake air filter plugs? • What if the compressor controller fails? • What if the compressor seal fails? • What if the internal compressor fails? • What if the relief valve fails to open? • What if the relief valve leaks or opens prematurely? • What if the wrong oil is used in the compressor? • • •
Dryer system	• What if the inlet valves are misaligned? • What if the wrong desiccant is used? • What if the desiccant is not changed? • What if the desiccant is loaded incorrectly? • What if the outlet valves are misaligned? • What if the desiccant begins to plug? • • •
• • •	• • •

5.0 Respond to the what-if questions

- **Immediate system condition or response**
- **Ultimate consequence of interest**
- **Safeguards**
- **Recommendations**

5.0 Respond to the what-if questions

Each what-if question must be answered by a group of subject matter experts who are knowledgeable about the design, operation, and maintenance of the activity or system.

Answering what-if questions generally defines the following:

Immediate system condition or response. The initial changes in activity or system conditions that would occur if the postulated situation (i.e., the *what-if*) were to occur

Ultimate consequences of interest. The eventual undesirable effects that the postulated situation could produce if it were not mitigated in some way. Includes the *worst-case* outcome as well as other significant, but perhaps less severe, outcomes of interest.

Safeguards. Equipment, procedures, and administrative controls in place to help (1) prevent the postulated situation from occurring or (2) mitigate the effects if the situation does occur

Recommendations. Suggestions for improvement that the team believes are appropriate; generally, suggestions for additional safeguards

There are three basic levels of documentation possible for a what-if analysis:

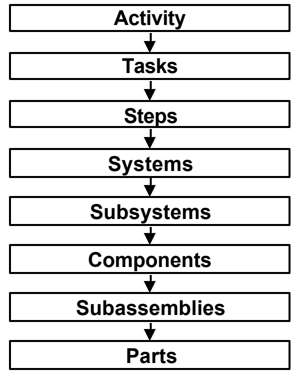
Level of Documentation	Description
Complete	Full responses for every question and a complete list of recommendations generated from the analysis
Steamlined	Responses to questions that result in suggestions for improvement, along with the complete list of recommendations generated from the analysis
Minimal	Complete list of recommendations generated from the analysis

Example of complete what-if documentation

Summary of the What-if Review of a Vessel's Compressed Air System

What if … ?	Immediate System Condition	Ultimate Consequences	Safeguards	Recommendations
1. The intake air filter begins to plug	Reduced air flow through the compressor, affecting its performance	Inefficient compressor operation, leading to excessive energy use and possible compressor damage Low or no air flow to equipment, leading to functional inefficiencies and possibly outages	Pressure/vacuum gauge between the compressor and the intake filter Annual replacement of the filter Rain cap and screen at the air intake	Make checking the pressure gauge reading part of someone's weekly round **OR** Replace the local gauge with a low pressure switch that alarms in a manned area
2. Someone leaves a drain valve open	High air flow rate through the open valve to the atmosphere	Low or no air flow to equipment, leading to functional inefficiencies and possibly outages Potential for personnel injury from escaping air or blown debris	Small drain line would divert only a portion of the air flow, but maintaining pressure would be difficult	—
• • •	• • •	• • •	• • •	• • •

6.0 Further subdivide the elements of the activity or system



6.0 Further subdivide the elements of the activity or system (if necessary or otherwise useful)

Further subdivision of activities or systems occurs only under the following conditions:

- Applicable data at the higher levels are not available
- Decision makers need information at a more detailed level

Often, only a few activities or systems must be subdivided.

If the above criteria apply to one or more subsystems, those subsystems may be further divided into components. In a similar manner, broad activities or tasks may be divided into individual steps. At each level, the process of performing the what-if analysis is repeated.

Example

Subsystems associated with the vessel's compressor system

- Electrical supply to the compressor
- Lubrication system
- Seal system
- Drive system, including the motor
- Mechanical compression system
- Control system
- Relief system
- Filter system

What-if analyses of any or all of those subsystems might occur if they were important systems from a risk perspective.

7.0 Use the results in decision making

- **Judge acceptability**
- **Identify improvement opportunities**
- **Make recommendations for improvement**
- **Justify allocation of resources for improvement**

7.0 Use the results in decision making

Judge acceptability. Decide whether the estimated risk-related performance for the activity or system meets an established goal or requirement.

Identify improvement opportunities. Identify elements of the activity or system that are most likely to contribute to future risk-related problems. These are the items with the largest percentage contribution to the pertinent risk-related factors of merit (safety, environmental, economic).

Make recommendations for improvement. Develop specific suggestions for improving the activity or system performance, including any of the following:

- Equipment modifications
- Procedural changes
- Administrative policy changes such as planned maintenance tasks, operator training, etc.

Justify allocation of resources for improvement. Estimate how implementation of expensive or controversial recommendations for improvement will affect future performance. Compare the risk-related benefits of these improvements to the total life-cycle cost of implementing each recommendation.